Letters to the Editor.

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Test-plates for Microscopes and Microscopic Definition.

IN NATURE of September 1 last (vol. 108, p. 10) I suggested that dry films of some of the aniline colours might prove suitable surfaces on which to rule the very fine lines required for test-plates. Since that time I have made some trials with films, using various dyes and various materials for the ruling-point. The dyes were eosin, saffranin, cyanine, methyl-green, methyl-blue, and methyl-violet. The last of these gave the most uniform films, leaving, on the evaporation of the solvent, a bright surface free from structure. Cyanine gave good films, though not quite so opaque as the methyl-violet for the same thickness. The others, either from a tendency to crystallise or from drying with a dull surface, were not so satisfactory.

The points for ruling were of steel, garnet, carborundum, and diamond. In all cases, except that of steel, the natural points found among broken fragments were chosen, and I doubt whether, without a somewhat elaborate grinding tool, an artificial point could be made so sharp as that given by the natural breakage.

The points have to be selected by trial, as the microscope is of little assistance in determining their real terminal shape. The only apparatus which was at hand for ruling purposes was a Cambridge rocking microtome, and the minimum interval between the lines (which corresponds, of course, with the thinnest section it could cut) was somewhat greater than 1/60,000 of an inch. No great accuracy in the spacing of the lines could be expected, but it is to the credit of the design of this microtome that there was no difficulty in getting well-separated lines at 30,000 per inch, and occasionally the 60,000 lines were quite apparent.

The uncertainty with these close lines was due, I think, chiefly to the rather rough workmanship of the bearings of the rocking arms, but in part, perhaps, to those of the point-holder.

The only real difficulty in close ruling is that of finding a fine enough point and applying it to the surface with a small enough force.

As mentioned in my previous communication, this force must not exceed a small fraction of a grain, and should remove the film but not scratch the glass. In the trials the point-holder was made as shown in Fig. 1, the materials being reed and split-cane put together with silk splicing and shellac cement.

This light and rigid frame could rock on the needle-points, one of which entered a conical pit, and the other a **V**-shaped groove in a fixed fitting which replaced the knife of the microtome. The whole forms a pendulum the effective weight of which (a few grains) is, say, w, of length L, which if displaced by an amount a exerts a force wa/L in the direction opposite to the displacement. Thus by placing the plate to be ruled at a suitable distance from the undisturbed position of the ruling-point the force can be adjusted as required.

While the film is being advanced for a fresh line the ruling-point is withdrawn by means of a silk fibre leading from the swinging frame to a bell-crank mounted on the fixed support.

A few photographs of bands ruled with this apparatus are given in Fig. 2. All these were made with diamond points. With a newly ground hardened steel point the 30,000 band was well shown, but the tool soon became too blunt for any spacing less than 15,000 per in. Garnet and carborundum points lasted fairly well for 30,000 per inch lines, but, as might be expected, were inferior to diamond so far as wear was concerned.

In the earlier trials from ten to sixty lines were ruled for each band, but later it was found that four or five lines were quite sufficient to show all the effects which various kinds of stage illumination have on the definition.

It is only with opaque and very thin objects that these can be examined to any advantage, thinness in this case being in comparison with the wave-length of light.

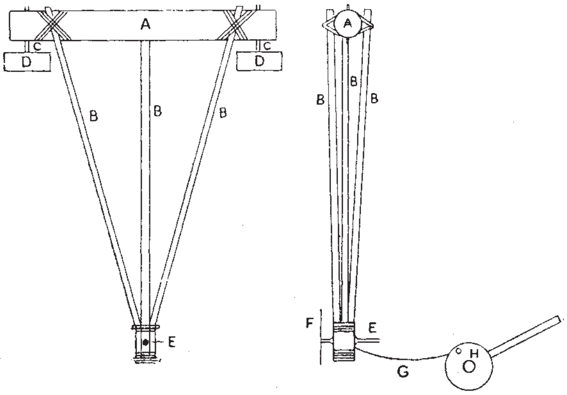

FIG. 1.—Holder for ruling point. A, Reed; BBB, split cane; CC, needle points; D, fixed support; E, diamond point; F, aniline film; G, silk fibre; H, bell-crank.

The methyl-violet films from which the photographs were taken were less than one-tenth of a wave-length in thickness, and, though not quite opaque, transmitted only a deep blue with some little red. The measurements of thickness were made by noting the displacements of the Newton's rings formed between a lens and the film at a place where part of the latter had been removed.

Test objects, such as diatoms, are much thicker than this, and, with them, what is seen in the field is merely a phenomenon in which the thickness and wave-length are both concerned.

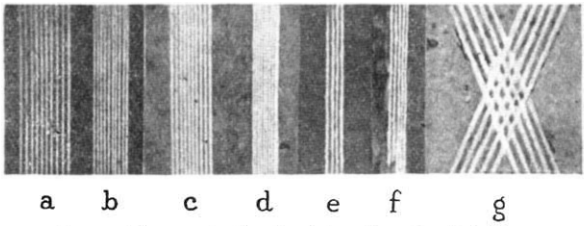

FIG. 2.—Photograph of bands ruled on films of methyl-violet

a,	10 lines	about	15,000	per in.	×350
b,	,,	,,	20,000	,,	,,
c,	,,	,,	17,500	,,	,,
d,	,,	,,	25,000	,,	,,
e,	4 lines	about	37,000	per in.	×600
f,	5 ,,	,,	35,000	,,	,,
g,	Intersection of bands		17,500	,,	,,

The photographic lines are not nearly so well defined as they appear when examined by the eye.

I think that the late Lord Rayleigh was the first to emphasise the fact that optical definition in general depends on the difference of the optical length of the paths of the rays the convergence of which forms the images of contiguous objects. Let A_1, A_2 (Fig. 3) be two objects in a line making an angle β with the focal plane of the lens, B_1, B_2 their images, and f_1, f_2 the conjugate focal lengths.

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The difference of length of the paths A_1, B_1, A_2, B_2 of rays making an angle i with the principal axis is $a \sin(i+\beta)$, and unless the average of this for all values of i exceeds $\lambda/4$, the images B_1, B_2 will appear connected, and will not be clearly separated until the average is about $\lambda/2$. From this it may be seen that not only is it impossible to separate the images of objects in the focal plane which are much closer together than $\lambda/2$, but also that the same limit defines the distance out of focus at which objects may be placed without altering the character of their images. This is a point which is well brought out by the lines on the aniline films.

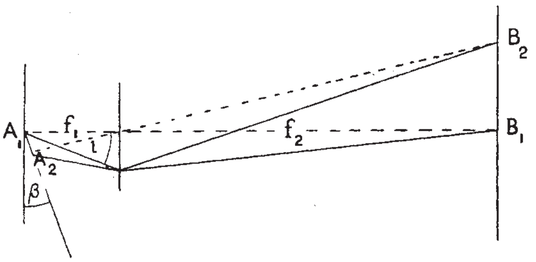

FIG. 3.

It may be asked what is the greatest magnifying power which can be usefully given to microscopes? Since objects closer together than $\lambda/2$ cannot form separate images, the greatest useful magnification is that which makes $\lambda/2$ visible to the eye.

A very good eye can just distinguish minutes of arc, or say objects separated by 1/350 in. at the distance of the eye from the stage. Then, taking the half-wave-length as the 1/100,000 of an inch, all details would be visible with a magnification of 100,000/350, or a little more than 280. Not all eyes, however, are capable of distinguishing minutes, and for convenience of observation, magnifications of twice this amount or more are used in practice, but the extra power reveals no new detail.

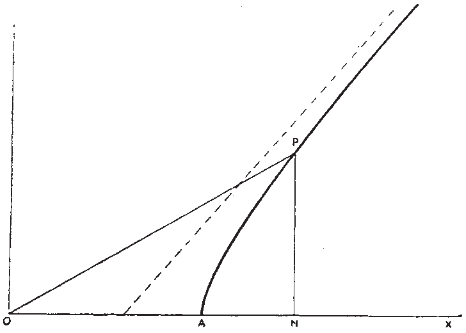

FIG. 4.—Form of plano-convex lens for the conversion of divergent rays into a parallel beam. O, Radiant point; OX, principal axis; PA, section of lens surface.

An idealised lens is merely a means of changing the radius of curvature of a wave-surface from f_1 to f_2 while preserving the constancy of the optical length of all the rays from focus to focus.

From these conditions the form of the lens which will achieve the result may be deduced. As a simple example, find the form of a plano-convex lens which will convert spherical waves originating at O (Fig. 4) into a parallel beam.

Let the convex surface of the lens cut the principal axis OX at A, and let the refractive index of the material be μ. The form of the surface is determined by the relation $OA+\mu AN=OP$. Elementary algebra shows that the curve PA is a hyperbola the asymptotes of which make an angle $\tan^{-1}\sqrt{\mu^2-1}$ with the axis of the lens. The complexity of actual objectives arises from the necessity of effecting the change of radius of curvature by means of spherical surfaces.

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The Antitrades.

I AM glad to support the appeal for observations of the motion of cirrus-clouds in the inter-tropical region and elsewhere made by Prof. van Bemmelen in his letter on the Antitrades (NATURE, February 9, p. 172). It is very interesting that the results which he has obtained by direct observation, with only such additional information from dynamics as may be got from a consideration of the general character of the Australian pressure, should coincide so excellently with results which we obtained here from the calculation of the distribution of pressure at various levels, and the assumption that the wind flows along the isobars.

There are some details in Prof. van Bemmelen's maps which indicate a flow of air *across the equator* which I should be disposed to modify in view of the peculiar conditions under which such a transference of air must take place. I hope to give the details of the information that we have compiled about this subject at some future time, and confine myself for the present to saying that the atmosphere seems to be able to use the circulation of air round a strip of doldrum region as a means of providing for currents which flow westward on the south side, and eastward on the north side, of the equator in a general slope of pressure from south to north across the equator. Thus the doldrum region becomes a sort of elongated clockwise "centre" for the winds of the monsoon north and south of the equator.

I would add also to Prof. van Bemmelen's appeal for observations of cirrus a plea for the extension of observations with pilot balloons. Methods are now so well understood that the authorities could easily provide a *technique* which could be followed by those accustomed to surveying and others, and would provide invaluable information The committee of the British Association which concerns itself about the upper air has already taken up the question, and if anyone who is in a position to help in this matter would communicate with me or with the secretary of the committee, Capt. C. J. P. Cave, of Stoner Hill, Petersfield, we shall be greatly obliged.

NAPIER SHAW.

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The Isotopes of Mercury.

IT appeared to be so definitely one of the fundamental assumptions of physics that pure mercury has a constant density under given physical conditions that when Brönsted and Hevesy announced that they had separated it into fractions of different density (see NATURE, September 30, 1920, p. 144) it appeared desirable that the separation should be confirmed by other observers. One of us finds that when mercury (purified chemically and by distillation in a vacuum) is distilled in a very high vacuum the first sixth of the original mercury condensed is of lower density than the last sixth. The difference in density found for these fractions was 44 parts in 1,000,000. This

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